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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Under this grant, the main thrust of the research was in the development of methods and concepts in reliability, availability, and maintainability, presently applicable and potentially applicable to the programs of the Air Force in particular and the Department of Defense in general. In addition, because of the general nature of the mathematical and statistical research performed, the results obtained are of value in a variety of other applied areas, and in mathematical and statistical theory.		

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**Final Scientific Report to Air Force
Office of Scientific Research**

Grant AFOSR-81-0038

September 1980--September 1981

**Statistical Aspects of Reliability, Maintainability
and Availability.**

**Reliability Center
Department of Statistics
The Florida State University
Tallahassee, Florida 32306**

**Myles Hollander and Frank Proschan
Co-Principal Investigators**

October, 1981

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distribution unlimited.**

Under Grant AFOSR-81-0038, a total of 14 research reports were issued, 27 papers were published in scientific journals or are in press or accepted for publication, and 3 books are in preparation.

The main thrust of the research performed under the grant is the development of methods and concepts in reliability, availability, and maintainability, presently applicable and potentially applicable to the programs of the U.S. Air Force in particular and the Department of Defense in general. In addition, because of the general nature of the mathematical and statistical research performed, the results obtained are of value in a variety of other applied areas, and in mathematical and statistical theory.

A partial list of topics treated may give some idea of the scope of the research performed under the Grant:

1. Accelerated life testing.
2. Reliability growth models.
3. A variety of maintenance models under the more realistic assumption that repair is imperfect.
4. Inference for the exponential life distribution.
5. Analysis of mean remaining life, both probabilistic and inferential.
6. Testing whether more failures occur later.
7. Testing whether a new item has stochastically greater life length than a used item of age t_0 .
8. Bayesian inference for coherent structures.
9. Further work on the extension of coherent structure theory to the multistate case.

10. Development of a new method for estimation of survival probability when data is incomplete.

11. Deriving optimal methods of inspection to determine the failed component(s) causing system failure.

12. Developing a new concept of negative dependence, deriving its properties, and obtaining applications in reliability.

13. Developing a theory of stochastic rearrangement inequalities and applying it to optimum construction of systems, testing for trend, and other areas of reliability.

14. Testing whether the mean residual life function displays a change in trend (i.e., is monotone increasing and then monotone decreasing).

15. Probabilistic and inferential treatment of the percentile residual life function (the analogue of the mean residual life function).

16. Testing whether one device possesses more of the "new better than used" property than does a second device.

17. Further work on shock models.

18. Analysis of censored data.

19. Types of qualitative dependence among random variables.

20. Analysis of Dirichlet processes.

21. Inference under the log rank test.

22. Renewal processes.

23. Approximation of DFR distributions.

24. First passage time distributions.

25. Random hazard functions.

Additional topics were treated but are not listed.

Papers Published During the Grant Period, In Press,
or Accepted for Publication.

- [1] A. Ahmed, N. A. Langberg, R. Leon, and F. Proschan. Two concepts of positive dependence, with applications in multivariate analysis. J. Mult. Anal. (to appear).
- [2] A. Ahmed, R. Leon, and F. Proschan (1981). Generalized association with applications in multivariate statistics. Ann. Statist. 9, 168-176.
- [3] L. Billard, H. Lacayo, and N. A. Langberg (1981). Generalizations of the simple epidemic process. J. of App. Prob. 17, 1072-1078.
- [4] M. Brown. Approximating DFR distributions by exponential distributions, with application to first passage times. Ann. Prob. (to appear).
- [5] M. Brown. Further monotonicity properties for specialized renewal processes. Ann. Prob. (to appear).
- [6] M. Brown. On the choice of variance for the log rank test. Biometrika (to appear).
- [7] M. Brown and F. Proschan. Imperfect repair. J. Appl. Prob. (to appear).
- [8] Y. Y. Chen, M. Hollander, and N. Langberg. Small-sample properties of the Kaplan-Meier estimator. J. Amer. Statist. Assoc. (to appear).
- [9] J. C. Conlon, R. Leon, F. Proschan, and J. Sethuraman. G-ordered functions, with applications in statistics. J. Mult. Anal. (to appear).
- [10] E. El-Newehi and F. Proschan (1980). Multistate systems: A survey. Mult. Stat. V, 523-541 (P. R. Krishnaiah, editor), Academic Press.
- [11] E. El-Newehi and F. Proschan (1981). Unified treatment of some inequalities among ratios of means. Proc. Amer. Math. Soc. 81, 388-390.
- [12] S. Fahmy and F. Proschan (1981). Bounds on differences of order statistics. Am. Statist. 35, 46-47.
- [13] R. C. Hannum, M. Hollander, and N. Langberg (1981). Distributional results for random functionals of a Dirichlet process. Ann. Prob. (to appear).
- [14] M. Hollander. A nonparametric test for parallelism. Ency. Stat. Sci. (Johnson and Kotz, editors), John Wiley, N.Y. (to appear).

- [15] M. Hollander. Hollander's extreme test. Ency. Stat. Sci. (Johnson and Kotz, editors), John Wiley, N.Y. (to appear).
- [16] M. Hollander. Tests for dependence. Ency. Stat. Sci. (Johnson and Kotz, editors), John Wiley, N.Y. (to appear).
- [17] M. Hollander. The bivariate symmetry test. Ency. Stat. Sci. (Johnson and Kotz, editors), John Wiley, N.Y. (to appear).
- [18] M. Hollander. The "New better than used" test. Ency. Stat. Sci. (Johnson and Kotz, editors), John Wiley, N.Y. (to appear).
- [19] M. Hollander and R. M. Korwar. Nonparametric Bayesian estimation of the horizontal distance between two populations. Colloquium on Nonparametric Statistical Inference. Academic Press (to appear).
- [20] M. Hollander, F. Proschan, and J. Sethuraman (1981). Decreasing in transposition property of overlapping sums, and applications. J. Mult. Anal. 11, 50-57.
- [21] J. Kitchin and F. Proschan (1981). Generalization of Block-Savits convolution result. Ann. Statist. 9, 437.
- [22] N. Langberg, R. Leon, J. Lynch, and F. Proschan. Extreme points of the class of discrete decreasing failure rate average life distributions. Optimization in Stats. (J. S. Rustagi, editor), Academic Press (to appear).
- [23] N. Langberg, R. Leon, and F. Proschan (1980). Characterization of nonparametric classes of life distributions. Ann. Prob. 8, 1163-1170.
- [24] N. Langberg, R. Leon, and F. Proschan. Characterization of partially ordered classes of life distributions. Statistica Nederlandica (to appear).
- [25] N. Langberg, F. Proschan, and A. Quinzi (1981). Estimating dependent life lengths, with applications to the theory of competing risks. Ann. Statist. 9, 157-167.
- [26] F. Proschan. Coherent structure theory. Ency. Stat. Sci. (Johnson and Kotz, editors), John Wiley, N.Y. (to appear).
- [27] F. Proschan and N. Singpurwalla (1981). A new approach to inference from accelerated life tests. I.E.E.E. Reliability R-29.

Reports Issued During Grant Period.

- [1] H. Joe and F. Proschan. Shock models arising from processes with stationary, independent nonnegative increments. AFOSR 78-115. October, 1980.
- [2] H. Lacayo, C. Pereira, F. Proschan, and C. Sarndal. Optimal sample depends on optimality criterion. AFOSR 78-116. October, 1980.
- [3] H. Joe and F. Proschan. Characterizations of discrete monotone failure rate. AFOSR 78-117. October, 1980.
- [4] M. Brown. Assessment of reliability for repairable systems. AFOSR 79-B-7. November, 1980.
- [5] R. Barlow and F. Proschan. Life distribution models and incomplete data. AFOSR 78-118. February, 1981.
- [6] M. Hollander. A nonparametric test for parallelism. AFOSR 78-119.
- [7] R. Berger and N. Langberg. Linear least squares estimates and nonlinear means. AFOSR 78-120. March, 1981.
- [8] M. Hollander. A distribution-free test for concurrence. AFOSR 78-121.
- [9] H. Joe and F. Proschan. Estimating a decreasing mean residual life distribution from complete or incomplete data. AFOSR 78-122. April, 1981.
- [10] P. Boland and F. Proschan. Periodic replacement with increasing minimal repair costs at failure. AFOSR 78-123. May, 1981.
- [11] M. Hollander. A distribution-free test for extreme reactions. AFOSR 81-124. August, 1981.
- [12] M. Brown. Approximating IMRL distributions by exponential distributions, with applications to first passage times. AFOSR 81-125. June, 1981.
- [13] K. Jogdeo and E. Bølviken. Monotonicity of the probability of a rectangular region under a multivariate normal distribution. AFOSR 81-126. June, 1981.
- [14] K. Jogdeo and F. Proschan. Negative association of random variables, with applications. AFOSR 81-127. September, 1981.

Books in Progress.

- [1] R. E. Barlow and F. Proschan. Inference and Data Analysis in Reliability and Data Analysis.
- [2] R. E. Barlow, F. Proschan, and N. D. Singpurwalla. Case Studies in Reliability and Life Testing.
- [3] K. Jogdeo and F. Proschan. Qualitative Notions of Statistical Dependence.

Finally, a number of distinguished and developing reliability theorists visited the Reliability Center for various lengths of time. These included Richard E. Barlow, Philip Boland (Ireland), Emad El-Neweihi, Peter Franken (East Germany), Kumar Jogdeo, Naftali Langberg (Israel), Moshe Shaked, and Nozer Singpurwalla.

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